instrumental values of the latitude. Circumstances prevented him from carrying on the work until six years later, when he took up the problem again. The results then obtained are published in a series of eighteen papers in the *Astronomical Journal* (1891–94), exclusive of a series of five papers upon a topic closely related thereto, namely, the aberration-constant. These papers have been noted from time to time in this column, so it is unnecessary to do more than refer to them now.

In connection with variable stars, besides the incidental work of observation and discovery which Dr. Chandler has contributed to it, his work has involved the collection of all the data in astronomical history, their discussion, and the formulation of the elements of their light-variations into numerical laws. His important researches upon cometary orbits are also well known to astronomers.

A LECTURE EXPERIMENT.

A FURTHER description of the use of the electric furnace recently exhibited at the Royal Society, for the purpose of lecture demonstrations, may be useful, as pictures, some six feet across, of the interior of the furnace may readily be projected on the screen. This is effected by the aid of the device which has already been given in NATURE (p. 17, Fig. 2). The result is really very beautiful, though it can only be rendered in dull tones by the accompanying illustration (Figs. A, B). It may be well, therefore, to state briefly what is seen when the furnace is arranged for the melting of metallic chromium. Directly the current is passed, the picture reflected by the mirror, E (Fig. 2, *loc. cit.*), shows the interior of the furnace (Fig. A) like a dark crater, the dull red poles revealing the metallic lustre and grey shadows of the metal beneath them. A little later these poles become tipped with dazzling white, and, in the course of a few minutes, the temperature rises to about 2500° C. Such a temperature will keep chromium well melted, though a thousand degrees more may readily be attained in a furnace of this kind. Each pole is soon surrounded with a lambent halo of the green-blue hue of the sunset, the central band of the arc changing rapidly from peach-blossom to lavender and purple. The arc can then be lengthened, and as the poles are drawn further and further asunder, the irregular masses of chromium fuse in silver droplets, below an intense blue field of light, passing into green of lustrous emerald; then the last fragments of chromium melt into a shining lake, which reflects the glowing poles in a glory of green and gold shot with orange hues. Still a few minutes later, as the chromium burns, a shower of brilliant sparks of metal are projected from the furnace, amid the clouds of russet or brown vapours which wreath the little crater; while if the current is broken, and the light dies out, you wish that Turner had painted the limpid tints, and that Ruskin might describe their loveliness.

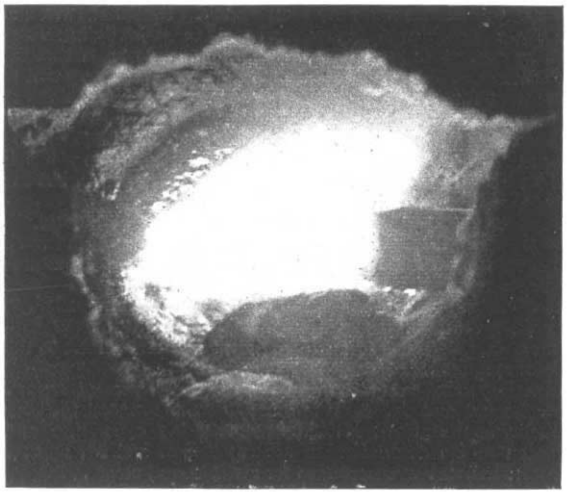


FIG. A.—This represents the interior of the furnace containing molten chromium as is seen either by reflection on a screen or by looking into the furnace from above, the eyes being suitably protected by deeply tinted glasses.

The effect when either tungsten or silver replaces chromium is much the same, but, in the latter case, the glowing lake is more brilliant in its turbulent boiling, and blue vapours rise to be condensed in iridescent beads of distilled silver which stud the crater walls.

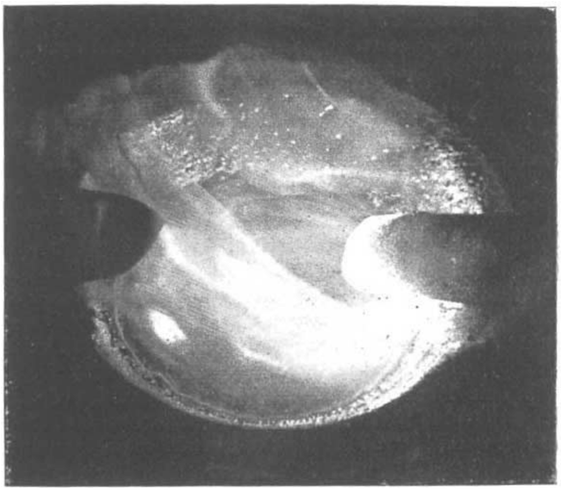


FIG. B.—In this case the arc was broken the instant before the photograph wa taken. The furnace contained a bath of silver just at its boiling point. The reflection of the poles in the bath, the globules of distilled silver, and the drifting cloud of silver vapour, are well shown.

Such experiments will probably lend a new interest to the us of the arc in connection with astronomical metallurgy, for, as George Herbert said long ago—

> "Stars have their storms even in a high degree,
> As well as we";

and Lockyer has shown how important it is, in relation to such storms, to be able to study the disturbances in the various strata of the stellar or solar atmosphere. Layers of metallic vapour which differ widely in temperature can be more readily obtained by the use of the electrical furnace than when a fragment of metal is melted and volatilised by placing it in the arc, in a cavity of the lower carbon.

W. C. ROBERTS-AUSTEN.

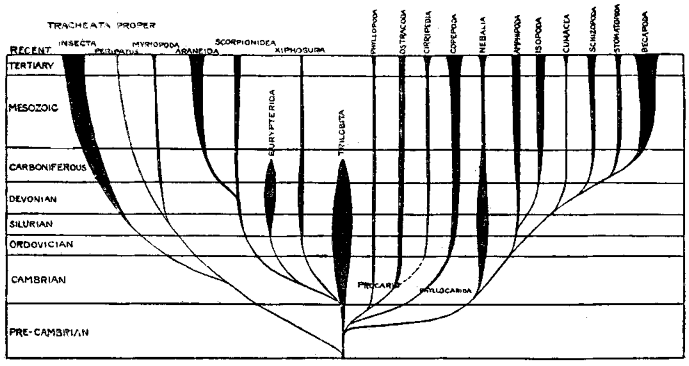
THE LIFE-HISTORY OF THE CRUSTACEA IN EARLY PALÆOZOIC TIMES.

IN his recent anniversary address to the Geological Society, the President, Dr. Henry Woodward, F.R.S., after the usual distribution of medals and awards, the reading of obituaries of deceased Fellows, and some preliminary matters relating to the affairs of the Society, including the moot question of the introduction of ladies as visitors to the evening meetings, devoted the remainder of his address to a brief discussion of "Some Points in the Life-history of the Crustacea in Early Palæozoic Times." Dr. Woodward continued as follows:—"Of the various groups of the Invertebrata whose ancestry extends into Palæozoic times, none possess a greater interest for the geologist than the Crustacea, whose existence is proved as far back as the Lower Cambrian rocks; while their near allies, the Arachnida, have been met with in strata as old as the Silurian.

"My earliest papers on the Eurypterida appeared in 1863 and 1864, and an account of *Stylonurus* and *Hemiaspis* was communicated to this Society in 1865, just thirty years ago. In that year (1865) I had the pleasure, with my friend and fellow-worker, the late J. W. Salter, F.G.S., of publishing a 'Chart of Fossil Crustacea,' in which an attempt was made to show the evolution in time of the various forms belonging to this class, graphically depicted on an engraved folding-sheet, with explanatory text. In it we pointed out that the main development of the crustacea in Palæozoic times consisted of the great groups of the Trilobita, the Eurypterida, the Xiphosura, the Phyllopoda, and the

Ostracoda. The faint beginnings of other great groups were also indicated, such as the Macrouran-decapods represented by *Anthrapalæmon* and other forms in the Coal Measures; the Stomatopods by *Pygocephalus Cooperi*, the Amphipods by *Gampsonyx*, both in the Coal Measures; and by *Prosoponiscus* in the Permian. Lastly, the Cirripedia, by the anomalous form *Turrilepas*, from the Wenlock Limestone.

"In November 1866, I laid before this Society the evidence upon which I based my arrangement of the *Pterygoti* and *Limuli* in one order, for which I adopted Dana's very appropriate name of Merostomata (or 'thigh-mouthed' animals)—expanded to include all those ancient crustaceans comprehended in the two sub-orders of Eurypterida and Xiphosura, and forming two groups *of long-bodied and short-bodied forms, quite parallel to the* Brachyoura and Macroura in the Decapoda; even the intermediate forms—corresponding to the Anomoura—being paralleled by the Hemiaspidæ (*Hemiaspis*, *Pseudoniscus*, &c.). This group formed the subject of a monograph published by the Palæontographical Society (1865–1878) comprising 17 genera and 84 species—69 of which are Palæozoic in age. The integrity of this group, founded on the researches of Huxley, Salter, Dana, Hall, and many others besides myself, has been firmly maintained, although many attempts have since been made to detach it from the Crustacea and place it with the Arachnida. For instance, it was proposed by Dr. Dohrn, in 1871, to include the Merostomata in a still larger division, under Haeckel's term Gigantostraca, which was made by expansion to embrace the Merostomata and the Trilobita, and to be placed *between* the Crustacea and the Arachnida.



THE EVOLUTION OF THE ARTHROPODA IN GEOLOGICAL TIME.

"In arguing for their retention before this Society in 1871 I wrote:—'Take away the trilobita from the pedigree of the crustacea, and I submit that one of the main arguments in favour of evolution to be derived from the class, so far from being strengthened, is destroyed. From what are the crustacea of to-day derived? Are we to assume that they all descended from the phyllopods and ostracods—the only two remaining orders whose life-history is conterminous with that of the trilobita? Or are we to assume that the arachnida are the older class?' 'If,' says Fritz Müller, 'the crustacea, insecta, myriapoda, and arachnida are indeed all branches of a common stock, it is evident that the water-inhabiting and water-breathing Crustacea must be regarded as the original stem from which the other terrestrial classes, with their tracheal respiration, have branched off.'

"In the above-quoted paper I pointed out that the young *Limulus*, when it quits the egg, has the hinder body as large as the head-shield, and the nine segments composing it are most clearly marked out, the abdominal spine being quite rudimentary and forming in fact the 9th segment. This is the so-called '*Trilobiten-stadium*' of Dohrn.

"'At this stage,' says Packard, 'the young swim briskly up and down, skimming about *on their backs* by flapping their gills, not bending their bodies.' This locomotion of the young *Limulus*, by swimming upon its back, near the surface of the water (by means of its gill feet), agrees very closely with the habit of *Apus*, of *Chirocephalus*, and *Artemia*, and is extremely suggestive of its affinity to the phyllopoda, with which, at this stage of its existence, it has many points in common, as well as with the trilobita.

"It is interesting to notice that the Xiphosura (king-crabs)—which form the surviving representatives of this ancient order of the Merostomata, and are so widely distributed in the Coal Measures of North America, Britain, &c.—have likewise been discovered as far back in time as the Upper Silurian of Lanarkshire, being represented by a small form which I named and described, in 1868, *Neolimulus falcatus*, having eight thoracic segments apparently free and movable, but wanting the tail-spine, which probably was developed later in life, or may have been represented by an extremely short terminal plate, as we see is the case in the young larval *Limulus*. Thus the earliest fossil king-crab known probably resembled closely the free-swimming larva of the living king-crab as it leaves the egg.

"*As to whether the Eurypterida—with their evidently aquatic* branchiated respiration, their jaw-feet provided with swimming- (not walking-) extremities—are in the direct line of ancestral relationship to the recent scorpions, I may refer again to my paper 'On some Points in the Structure of the Xiphosura,' &c.: —'This is one very strong argument, to my mind, in favour of the higher zoological position of *Pterygotus*—that, being extremely larval in its anatomy, it consequently possessed the capacity for further development, and so has been modified and disappeared' —its latest representatives being met with in the Coal Measures, where the then earliest known examples of fossil scorpions had also been found. But the discovery, almost simultaneously, by Thorell and Lindström in Gotland; by B. N. Peach in Scotland; and by Whitfield in North America (in 1885) of actual pulmonated land scorpions in rocks of Upper Silurian age (as far back, in fact, in geological time as the earliest known occurrences of *Pterygotus*, *Slimonia*, and *Eurypterus*) indicates that the air-breathing scorpions were derived from a *still earlier* and as yet undiscovered aquatic progenitor possibly in Cambrian or pre-Cambrian times.

"Simultaneously with the commencement of my own work on the Merostomata, J. W. Salter undertook a monograph on the British Trilobites for the Palæontographical Society in 1864. No one who takes up this fine work of our old friend can avoid a feeling of regret that Salter's valuable life and splendid palæontological knowledge should not have been longer spared to us to carry on to its completion this most important service.

'Following up the progress of our knowledge of the trilobites, I may note that Dr. Henry Hicks made his first communication to this Society in 1865 on the genus *Anopolenus*, and between 1871 (when he came to London from the happy hunting-grounds of St. David's and joined the Geological Society) and 1876, he communicated to this Society a series of papers on the faunas of the 'Menevian,' the Lingula Flags, Tremadoc Slates, and Arenig series, giving descriptions of no fewer than thirty-four species of trilobites, belonging to eighteen genera, from those ancient rocks.

"But numerous as are these additions to our knowledge of the trilobites of Wales, they only represent a part of Dr. Hicks's discoveries, many of which were announced by Salter; the most important being that of the finding of a large *Paradoxides* at St. David's, proving the existence of a Middle Cambrian or '*Paradoxides*-zone,' coextensive with the vast area over which these early rocks have been observed, and occupying a persistent horizon throughout Europe and America.

"A brief reference must here be made to the papers published by that excellent geologist and naturalist, the late Thomas Belt, F.G.S., in 1867 and 1868, on new trilobites from the Upper Cambrian rocks of North Wales, and on the Lingula Flags or Ffestiniog group of the Dolgelly District, with figures and descriptions of four species of *Olenus* (non-*Conocoryphe*) and four species of *Agnostus* from Dolgelly. In 1888 I was so fortunate as to be able to record the first discovery of trilobites (*Conocoryphe viola*) in the Longmynd Group, Penrhyn quarries, Bethesda, near Bangor, in North Wales.

"The remarkable fauna of the *Olenellus* or Lowest Cambrian zone, originally discovered in America by Dr. Emmons in 1844, was first recognised in Europe by the late Dr. Linnarsson in 1871, in the basal zones of the Cambrian near Lake Miösen in Norway, but its typical genus *Olenellus* was then referred by him to the allied but more recent genus *Paradoxides*. This referenc was corrected by Prof. Brögger in 1875; and the various brilliant papers on the Primordial formations by this author have given the *Olenellus*-fauna a marked and peculiar interest. In 1882 Linnarsson next made known the existence of the *Olenellus*-fauna in Scania, at the base of the Swedish Cambrian. In 1886 the same fauna was detected by Mickwitz in the Lower Cambrian of Russia (Esthonia), and this Russian fauna was figured and described in detail by Dr. F. Schmidt, of St. Petersburg. In 1887 Dr. Holm reported the existence of the *Olenellus*-fauna in the Cambrian of Lapland, where it was first detected by Mörstell in 1885. Thus the existence of this remarkable fossil group, the oldest well-marked fauna recognised by geologists in the Lower Cambrian, had already been demonstrated, in 1888, in three main regions, namely: (1) in the region of the Rocky Mountains; (2) in the region of North-eastern America; (3) in the region drained by the Baltic Sea. Up to 1888 no recorded account of the discovery of *Olenellus* from the British Isles had been published, the oldest fauna described being the overlying *Paradoxides*-zones or Middle Cambrian formation.

"The first recognisable traces of *Olenellus* in Britain were discovered by Prof. Lapworth in 1885. Further collections were made in 1887 and 1888, on the flanks of Caer Caradoc, Shropshire, and the species was named, in honour of Dr. Charles Callaway, *Olenellus Callavei*. Later on it was figured and described in the *Geological Magazine* for 1891.

"In August 1891, Sir A. Geikie announced, at the British Association meeting in Cardiff, the discovery of *Olenellus* by Messrs. Peach and Horne, in blue-black shales, a few feet below the "Serpulite Grit" of the Cambrian rocks of North-west Scotland, in the Dundonnell Forest of Ross-shire. The description of "the *Olenellus*-zone of the North-west Highlands" formed the subject of a most valuable paper by Messrs. Peach and Horne, read before the Geological Society on February 10, 1892, and a new species of *Olenellus* is described and named *O. Lapworthi* by these authors. Mr. B. N. Peach, F.R.S., communicated a second paper, "Additions to the Fauna of the *Olenellus*-zone of the North-west Highlands," on June 20, 1894; in which, in addition to *O. Lapworthi*, he describes and figures *O. Lapworthi* var. *elongatus*, *O. reticulatus*, *O. gigas*, *O. intermedius*, and *Olenelloides armatus*.

"'The Fauna of the Lower Cambrian or *Olenellus*-zone' forms the subject and title of an admirable monograph by Mr. C. D. Walcott, F.G.S., which, with the exception of the subsequent discovery of an *Olenellus*-fauna in the Lower Cambrian of the Scotch Highlands (already referred to), gives us a very complete and up-to-date account of this interesting and oldest fauna. About eighteen widely distributed localities are shown on the map of North America from British Columbia to Labrador, and as far south as Texas; whilst in Europe we have Spain, North and South Wales, the Scottish Highlands, Norway, Sweden, Finland, Bohemia, Bavaria, Podolia, Sardinia, Petchoraland, and the Ural Mountains. Omitting trails, burrows, and tracks, the *Olenellus*-fauna has yielded fifty-five genera of organisms, fifteen of which are Trilobites.

"We may now add yet another locality in which this remarkable fauna occurs, as proved by the presence of the remains of *Olenellus* and the pteropod *Salterella*; namely, in Western Australia, where it was discovered by Mr. Hardman in 1886.

"I must here refer to the discoveries of the limbs of trilobites. In 1870 the late E. Billings, the Palæontologist of the Geological Survey of Canada, brought before the Geological Society and described a specimen of *Asaphus platycephalus*, from the Trenton Limestone of Ottawa, Canada, exhibiting remains of eight pairs of limbs, corresponding with the eight free and movable segments of the body, and showing the hypostome still attached to the doublure of the anterior border of the cephalic shield; traces of two appendages under the caudal shield were also visible. On that occasion I exhibited a specimen of *Asaphus* from the same locality and horizon, showing evidence of a small 7–8-jointed palpus lying at the side of the hypostome apparently in its original position. After some remarks on the superficial character of trilobites, I added:—'The prominence of the hypostome in the trilobita reminds one even more strongly of the genus *Apus* than of the isopods, and it is quite reasonable to expect in the trilobita a more generalised type of structure than that which marks the modern representatives of the class.'

"In 1881, after many years of untiring labour, Charles D. Walcott furnished most conclusive proofs of the existence of appendages to the cephalic, thoracic, and abdominal divisions of *Calymene*, *Ceraurus*, and *Acidaspis*. His researches have been carried on by the method of making thin transverse and longitudinal sections of rolled-up specimens. He has shown that the ventral body-wall of the trilobites was bounded inferiorly by a thin chitinous membrane, which was attached to the lower margin of the dorsal exoskeleton all round. This ventral membrane was supported by calcified arches, which gave attachment to the appendages beneath. He further established the existence of a row of articulated cylindrical limbs, on each side of the middle line. Walcott described the thoracic appendages in *Calymene* as slender six-jointed walking-legs (endopodites) with a single pointed termination, the basal segment giving rise to a branch appendage (exopodite). On each side of the throracic cavity he also described a row of bifid spiral appendages, of the nature of gills, and he suggested that branchiæ were attached to the bases of the thoracic limbs as well. The abdominal or pygidial rings carried appendages, a pair to each segment, but they do not appear to have differed from the thoracic limbs, save in size. The mouth is situated behind the hypostome, and has four pairs of jointed manducatory organs, the bases of which are modified to serve as jaws; the hindmost pair being the largest, and expanded at the distal extremity into a swimming-organ.

"The correctness of Billings's views, as to the nature of the thoracic limbs of *Asaphus platycephalus*, was further confirmed by the finding of a specimen of *Asaphus megistos*, in the Ordovician rocks of Ohio, which shows the under surface with its appendages, described by Dr. I. Mickleborough. This specimen shows two pairs of maxillipeds or jaw-feet, eight pairs of walking-appendages, corresponding to the eight pairs of free thoracic segments, each limb having about six joints. The under side of the coalesced segments of the abdomen (pygidium) reveals a series of from twelve to sixteen similar paired appendages, diminishing rapidly in size from before backwards to the extremity. A broad median groove extends along the under side of the thorax and abdomen, and probably represents the space once occupied by the sternites or, possibly, the straight intestinal canal, observed by Barrande in some trilobites from Bohemia. Traces of supposed branchial filaments have also been observed in this specimen, apparently attached to the thoracic legs.

"No further addition had been made to our knowledge of the appendages of triobites until July 1893, when Mr. W. D. Matthew, a student of Columbia College (N.Y.), communicated the result of his examination of several specimens of *Triarthrus Beckii*, obtained by Mr. W. S. Valiant from the 'Hudson River Shales' (Ordovician), near Rome, New York. After recording the extent of our previous knowledge derived from the important researches of C. D. Walcott, he proceeds to describe the additions which the specimens from Rome have supplied. These trilobites are found in a soft, fine, black shale, and are perfectly well preserved. The most noticeable character is the presence of long, slender, many-jointed whip-like appendages attached to the front of the head, closely resembling the flagellate antennæ of other crustaceans. These originate beneath the anterior border of the head-shield, and are as long again nearly as the glabella itself. Mr. Matthew also was able to detect a series of walking or swimming-legs, one a narrow, jointed, cylindrical leg, the other thin, broad, fringed with a comb-like structure similar to the gills of many crustacea.

"The next communication is from Mr. C. E. Beecher, of New Haven, Conn., 'On the Mode of Occurrence and the Structure and Development of *Triarthrus Beckii*.' The material gathered for the Yale University (by the aid of Prof. Marsh), near Rome, New York, is probably some of the best which has been obtained, and has been carefully examined and described by Mr. Beecher.

"In their present condition the specimens from Rome contain very little calcite, nearly the entire calcareous and chitinous portions of the trilobites being replaced by a thin film of iron pyrite. To this cause is doubtless due the preservation of delicate organs and structures which would otherwise have been destroyed.

"The specimens thus preserved occupy an extremely restricted vertical distribution, but within this range they are nearly all complete, and preserve their appendages. They are of all ages, from larval forms up to full-grown individuals, whilst the adjacent strata contain a rather sparse fauna in which the trilobites are generally fragmentary and without appendages. The author believes that, in the majority of beds in which trilobites are found, the remains met with represent the exuviæ of living animals that have cast their shell, rather than the tests of dead individuals. In this particular deposit the appendages are apparently in the position which they occupied during life, and not such as would be assumed in the cast-off shells of recent crustacea.

"Mr. Beecher mentions another interesting point, namely, that nearly all the specimens are found with the back down, which is explained by suggesting that, although they lived with the ventral side downwards, the gases in the viscera produced during decomposition were sufficient to overturn the animal and allow it to be buried by the accumulation of the fine sediments in the position in which it is now found.

"The appendages of *Triarthus* appear now to be very well made out. The antennæ, as seen in a number of specimens, were simple multiarticulate flagella, which Walcott has shown extend backwards to the lateral margin of the hypostome, so that they occupy exactly the same position as do the first antennæ in recent *Apus*.

"Two small appendages, like simple palpi, with broad basal joints, which may represent the maxilla, are seen in one of Walcott's specimens, and there were probably four pairs of similar cephalic appendages, besides the simple flagellate antennæ, more or less modified to serve as mouth-organs.

"Each segment bears a pair of biramous appendages originating at the sides of the axis, as in other trilobites. The anterior legs are the longest, and the others gradually become shorter towards the pygidium. Each limb consists of two nearly equal branches, the 'endopodite' and 'exopodite,' which may be correlated with the typical crustacean primitive limb, and are well displayed in the adult *Mysis;* in the biramose natatory-feet of the zoea of the common shore-crab (*Carcinus*); and retained in the appendages of the abdomen of the adult lobster (*Homarus*). Practically, these biramose limbs are reproduced along the entire series of free segments. The appendages belonging to the pygidium closely resemble the branchigerous feet of *Apus*, and may evidently be correlated with typical phyllopod limbs.

"The first point insisted upon by all systematic zoologists—long before the finding of appendages had thrown so much new light upon our investigations—was that the great variability in the number of the segments in trilobites was a feature which distinctly connected them with the phyllopoda. Bernard considers of greater importance still the gradual diminution of the size of the segments posteriorly, which remarkable feature the trilobites share with *Apus*. I would also call attention to the fact that those earlier trilobites which best exhibit this large number of segments, such as *Olenellus*, *Paradoxides*, &c., are likewise remarkable for the simplicity and exact similarity of their segments, being a serial repetition of one another, and even the coalesced segments forming the head-shield share the same resemblance with the free posterior thoracic and abdominal ones. Bernard has given expression to the idea most aptly when he writes (*op. cit.* p. 412):—"The adult is but the grown, not metamorphosed, larva—grown by the continual development of segments from before backwards, until at a certain stage this process becomes fixed, and we have the adult *Apus* with a number of fixed rudimentary segments. This fixation of a number of undeveloped segments is visible also in many trilobites.

"In the earlier forms (as *Olenellus*) these rudimentary posterior segments still remain free; but, as a rule, they are coalesced to form the plate-like pygidium so characteristic of the trilobites.

"Turning to the appendages, the simple multisegmented flagellate antennæ are extremely characteristic of the crustacea, being met with in lowly copepods and highly-developed decapods.

"The biramose paired limbs are quite a primitive type, like the segments to which they are attached, exceedingly simple, yet characteristic, and with the exception of the antennæ and the four succeeding pairs of appendages, which are modified to serve as mouth-organs (maxillæ and maxillipeds), the whole series are simple biramose natatory or walking-feet, such as persist still in adult *Mysis* and many other recent crustacea.

"The eyes in trilobites closely resemble those of other anthropods, but vary somewhat in position, and also in development, in some genera the eyes being altogether absent, as in *Ampyx*, *Ceraurus*, &c., whilst in others, like *Æglina*, they are enormously exaggerated in size. In some genera the eyes are hyaline, the faceted surface being covered with a fine transparent layer, whilst in others the facets appear prominently on the surface. It is suggested by Bernard that the minute pore observed in the head, near the compound eye in several genera (*Trinucleus*, *Acidaspis*, *Calymene*, *Ampyx*, *Griffithides*, *Phillipsia*, &c.), may be analogous to the pore in the head-shield of *Apus*, and be the opening into the water-sac covering the eyes; and whilst in some genera of trilobites this water-sac may have existed, it may have degenerated in others, leaving the eye in contact with the outer cuticle, which covered it like a thin transparent membrane. In none of the trilobites have larval eye-spots been observed.

"Dr. Lang held the view (in 1891) that if a fifth pair of cephalic limbs were found comparable with the anterior antennæ, trilobites might then be regarded as primitive entomostraca, to be derived from the same racial form as the phyllopoda.

"Walcott is of opinion that the trilobita formed a distinct branch, which diverged at a very early date from the phyllopoda, and having expended its vital energy in Palæozoic times it disappeared. He adds: 'Probably two thousand species and one hundred or more genera are known from Palæozoic strata. With this great differentation the initial vital energy of the group became impaired, and the trilobita died out at the close of Palæozoic time.

"I willingly adopt the view that the trilobita are ancestrally connected with *Limulus;* that *Limulus* may be related through *Hemiaspis* with *Eurypterus;* but all the intermediate forms have not yet been met with. That some ancestral Eurypterid must have given rise to *Scorpio* cannot, I think, be doubted; but it must have been in pre-Silurian times, for Peach and Lindström's *Palæophonus* had already appeared in the Upper Silurian of Lanarkshire and Gotland as a terrestrial pulmonated form, while a similar land-scorpion had been discovered by Whitfield in the Silurian of America.

"The Phyllopoda deserve consideration from a geological standpoint, a representative of *Apus* (*Protocaris Marshii*) having been met with in the Lower Cambrian of Vermont, U.S. Some of the living genera are naked (*Branchipus* and *Artemia*), but in most the front portion of the body is protected by a shield-like carapace (*Apus*), or it may be enclosed, as in *Estheria*, in a bivalve shell. The fossil remains of bivalved phyllopods, *Estheria* and *Leaia* were described by Prof. T. Rupert Jones as far back as 1862 in the Palæontographical Society, where he defines nineteen species ranging from the Old Red and Carboniferous upwards.

"The most ancient of these shield-bearing crustaceans, originally placed with the phyllopoda and having a single modern analogue (*Nebalia*), have now, by general consent, been removed and placed under the order Phyllocarida, a name suggested by Dr. A. S. Packard in 1879. The fossil forms referred to this order were originally studied and noticed by M'Coy, Salter, Barrande, Clarke, and have subsequently been fully described by Prof. T. Rupert Jones and myself.

"Metschnikoff, who studied the embryology of *Nebalia*, considered it to be a 'phyllopodiform decapod.' Besides the resemblance to the decapods, there is also a combination of copepod and phyllopod characteristics. The type is an instance of a generalised form, and is of high antiquity, having made its appearance in Cambrian times, when there lived (if we regard the relative size of most crustacea, and especially that of the living *Nebalia*) gigantic forms. Such was the Silurian *Ceratiocaris ludensis*, which was probably more than two feet in length.

"The modern *Nebalia* is extremely small, about ¼ inch in length, but a newly-described species, *Nebaliopsis typica*, Sars, measures as much as 1⅗ inch, with the body compressed, and the carapace bivalved, as in *Limnadia*, one of the genuine phyllopods. There is a large movable rostrum overhanging the head; stalked eyes; the cephalic portion carries two pairs of antennæ and three pairs of special mouth-organs (mandibles and maxillæ); the thoracic segments bear eight pairs of short, leaf-like respiratory-feet, which are followed by six pairs of (abdominal) simple swimming-feet, four being large and two rudimentary, while the last two segments (seventh and eighth) are destitute of appendages, the body terminating in an elongated phyllopod-like caudal fork. Compared with *Nebalia*, the fossil forms give evidence of an articulated rostrum; traces of antennæ; the presence of a pair of strong mandibles; of a large expanded shield in some, and of a folded or bivalved carapace in others; of the presence of seven or eight body-segments, sometimes carrying branchigerous appendages, the terminal segment carrying a central caudal spine and two lateral shorter ones. It seems highly probable that the old giant pod-shrimps (*Ceratiocaris*, *Dithyrocaris*, &c.), whose remains occur in the Palæozoic rocks from the Cambrian to the Carboniferous, are represented by the minute living *Nebalia*, and that these early forms may have given rise to, and have been the forerunners of, the modern Malacostraca. 'In *Nebalia*,' says Claus, 'we probably have to do with an offshoot of the phyllopod-like ancestors of the Malacostraca, which has persisted on to the present time.'

"The genus *Estheria* existed in the fresh and brackish waters of the Devonian Period, in Livonia, Caithness, and Orkney, and also in Nova Scotia and Scotland. It flourished in the European area at several of the Upper Carboniferous stages, and was well represented in the Secondary and Tertiary rocks; it is also living, and has a world-wide distribution.

"The Phyllocarida seem in some cases to afford examples of persistency of type, and in others of local or temporary specialisation. One of the oldest known is the Cambrian *Hymenocaris*, a prototype of the recent *Nebalia*. *Caryocaris* of the Arenig series possibly belongs to the same group; and the Upper Silurian *Ceratiocaris* carries the form to a high degree of perfection; but until we meet with the *Nebalia* of to-day we have no tangible links in this series in intermediate geological times. Walcott's Cambrian *Protocaris* is quite susceptible of being regarded as a predecessor of the living *Apus*. The Carboniferous *Dithyrocaris* and its allies stand probably in the relation of genealogical links. But much more research among these interesting lower crustacean fossils is required before their phylogenetic relationship can be fully elucidated.

"The Ostracoda, which have the entire body enclosed in a shell or carapace composed of two valves united along the back by a membrane (represented by such forms as *Cypris*, *Cypridina*, *Candona*, *Beyrichia*, *Primitia*, &c.), are chiefly dwellers in shallows, and occur both in fresh and salt water; they are usually of minute size; but there are deep-sea types which attain comparatively large dimensions (an inch long). They are met with in rocks of almost all ages from the Cambrian upwards. To speak of them here is to recall the nearly life-long labours (from about 1840) devoted to their elucidation by Prof. T. Rupert Jones, who has described many hundreds of these primitive crustacea from rocks of every British formation as well as from very many foreign countries.

"Great as are the transformations which these organisms have witnessed in the long cycles of geological change from Lower Cambrian to modern time, they present, nevertheless, a general facies, and (like the genus *Lingula* amongst the brachiopoda) must be looked upon as one of those persistent types which possess enormous power of multiplication, so that entire beds of rock may be said to be composed of their microscopic tests. The living species also possess exceptional powers of endurance and provision for the preservation of their lives in periods of drought, often retaining their vitality in a dormant state perhaps for years; thus they have persisted through all the vicissitudes of geological time, represented by the entire succession of the stratified rocks; 'all things changing, but themselves unchanged.'

"None of the older Ostracod genera exist now; but some of the existing forms of the Cyprididæ, Cytheridæ, and Cytherellidæ are fully represented by predecessors in the Palæozoic rocks. The wonderfully well-preserved *Palæocypris Edwardsii*, discovered by Dr. C. Brongniart, enclosed in transparent silica, displaying the soft parts of the animal as perfect as in life, from the Coal Measures of St. Etienne, is evidence of the existence of Cyprids in that far-off time.

"I have endeavoured to depict in a diagram (p. 115) the evolution of the Arthropoda in geological time.

"In concluding this brief excursion over the abysses of Palæzoic time, I have only been able to bring under your notice a few isolated points of interest in the crustacean fauna which lie in the depths of these ancient deposits. They may, however, serve to show that this group of lowly existences is not destitute of interest for the biologist. There may also be a possibility of connecting these isolated observations so as to show their bearing upon the greater question of the development of life.

"In order, however, to do this effectively I must ask you to accompany me next year in a second excursion over the newer Palæozoic and Kainozoic seas, where, nearer land and in shallower waters, we shall find a still greater variety of life-forms to study.

"Two conclusions may be drawn from our observations, namely, (1) that the ancient faunas of the earth were far more widespread, more simple and more uniform than are our recent faunas; and (2) if, as the researches of geologists seem to indicate, other sedimentary rocks exist, *older* than the Lower Cambrian, then we may hope to gather evidence of still earlier and more simple forms of life than are met with in the '*Olenellus*-zone.' We are fully justified in concluding that such must actually have existed, because we find in the Lower Cambrian evidence of a quite considerable fauna belonging to several divisions which, although lowly in themselves, are nevertheless already so clearly differentiated one from the other as to prove to us that we are still, both biologically and chronologically, very far removed from the commencement of life on the earth."

SCIENTIFIC SERIALS.

American Journal of Science, May.—On the colour relations of atoms, ions, and molecules, by M. Carey Lea. Part 1. The colour or absence of colour of an element is a function of its atomic weight. No element having ions coloured at all valencies can belong to the same natural group with elements having colourless ions only. The entire class of elements with colourless ions is divided into nine great natural groups, as follows:—H, F, Cl, Br, I; Li, Na, K, Rb, Cs; Ca, Sr, Ba; Sc, Y, La; Be, Mg, Zn, Cd, Hg; B, Al, Ga, In; C, Si, Ge, Sn, Pb, Th; N, P, As, Sb; O, S, Se, Te. This first great division of the elements includes all those whose ions function as anions, and also part of the cathions. Intermediate between the two chief divisions are eleven transitional elements, viz. Ti, V, Cu, Nb, Mo, Ag, Ce, Ta, W, Th, Bi. These have ions which at some valencies are coloured and at others colourless. These are cathions only. With atomic weights ranging from 1 to 47 the atoms are colourless; 52 to 59 coloured; 65 to 90 colourless; 103 to 106 coloured; 112 to 139 colourless; 145 to 169 coloured; 192 to 196 coloured. Elements whose place in the numerical series falls between these periods have both coloured and colourless atoms. The six heaviest metals at the end of the series are alternately coloured and colourless.—Argon, Prout's hypothesis, and the periodic law, by Edwin A. Hill. A very interesting question connected with the discovery of argon is what will be the effect of these researches upon Prout's hypothesis? It is possible that argon has been an unsuspected cause of error, which, when properly allowed for, will show the ratio of H to O to be almost exactly 1 to 16. This would make so many atomic weights even or half multiples of H as to render probable the generation of the elements from a common form of matter by the continued addition of some one or more constant increments of mass.—Relation of the plane of Jupiter's orbit to the mean plane of 401 minor planet orbits, by H. A. Newton. The secular perturbation of the orbit of a minor planet by Jupiter is such that the inclination of the orbit plane is not greatly changed, but the node has a constant motion. Whatever may be the distribution of the poles of these orbits at one epoch, the tendency of the secular perturbation by Jupiter is to finally distribute them symmetrically around the pole of Jupiter's plane. The present inclination of the mean plane to Jupiter's plane is 0°·43.

American Meteorological Journal, May.—The cause of cyclones, by Prof. A. Woeikof. The article deals chiefly with two points mentioned in a former paper on this subject by Mr. Dines. Dr. Woeikof considers that the balloon ascent from Munich on December 11, 1890, showed that, while there is no cooling of the free air in calm anticyclonic weather, the radiation of the surface of the snow cools the surrounding air, even on an isolated mountain. With regard to the suggestion that the latent heat set free by condensation is sufficient to cause a storm, he points out that the heat set free by copious condensation in India does not produce storms.—Meteorological problems for physical laboratories, by Prof. C. Abbe. Few physical laboratories have conveniences for studying aero-dynamics, but the author, with the assistance of Prof. C. F. Marvin, gives a list of thirty-seven subjects for experimental investigation which demand attention from meteorological students.—Long range weather forecasts, by Prof. H. A. Hazen. The author puts forward a series of crucial tests of weather forecasts, more particularly with the view of showing the fallacy of the predictions based on the positions of the moon, planets, &c.—There is also an article by F. B. White on topographic influence on the winds of the weather maps, which frequently show erratic winds, having no dependence on the barometric gradients charted with them.